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A HISTORICAL NOTE CONCERNING SALT IN VERTEBRATE BLOOD AND IN THE SEA

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ABSTRACT In 1902 and 1903 G. von Bunge and A. B. Macallum became impressed independently with the similarity between the salt content of ocean water and vertebrate blood. Von Bunge's ideas concerned NaCl and were stated in a physiology text. Macallum's ideas, related mostly to the proportions of Na, K, and Ca in sea water and blood, were set forth in a series of papers ending in 1926. Bayliss (1927) and Pearse and Gunter (1957) accepted this thesis. Conway (1943, 1945) questioned it on the grounds that the salts from land erosion do not correspond to those in the sea. However, Rubey (1951) has shown that sea salt has come from the deep Earth rather than erosion. All ensuing discoveries have corresponded to that idea. As a side issue, the theory of the freshwater origin of fishes has succumbed to a large number of questioning papers. Now the von Bunge-Macallum theory is generally unquestioned.

Some 81 years ago a German professor named Gustav von Bunge first sensed the importance of salt in the sea and in vertebrate blood, including the fluids of men and other mammals. He stated this idea in the fourth edition of his *Lehrbuch der physiologischen und pathologischen chemie.*

The fourth edition of the physiological chemistry text by von Bunge was translated by Florence A. Sieveking Starling and edited by her famous husband and published in this country as a *Textbook of Physiological and Pathological Chemistry* by Bunge (1902), P. Blakiston's Son and Co., Philadelphia. In England the same book was published by Kegan Paul. Presumably the fourth German edition was published in the same year, although I have not seen it.

The attention of von Bunge seems to have been centered upon salt alone, which in the language of his day meant NaCl. Further developments led to more complicated ideas, but von Bunge's thoughts seem to have been the beginning of the salinity picture of blood today as it involves physiology.

Von Bunge drew many sentient conclusions about the kidneys, the blood of vertebrates, and the distribution of salts of the alkaline earth metals sodium and postassium. He pointed out that the carnivores and meat-eating men did not crave salt (NaCl) but that plant-eaters in animal populations and human society were always craving it. He said people probably overloaded their kidneys and caused nephritis by taking too much salt. This admonishment has a distinctly modern ring, but today the reasons are stated somewhat differently, although von Bunge may have been very close to correct for it is now known that the kidneys have as much to do with high blood pressure as the heart does, or more.

Von Bunge called attention to the fact that vertebrate fluids are replete with NaCl, but plant tissues are potassium dominated. Thus the herbivores are always seeking salt (NaCl) for their blood and other fluids.

Von Bunge said on page 101 of this treatise, "I am, however, convinced that the remarkably high percentage of salt in vertebrate animals, as well as the desire to take salt with our food, can only be satisfactorily explained by the theory of evolution." That was a sharp insight due to his predilection for speculative thinking with the evidence available to him.

He noted that most plants are rich in potassium and poor in sodium, except for marine species, and that the invertebrate land animals are similar to typical land plants in salt content. In summary, he said (p. 103), "These are facts which lead most readily to the interpretation that the vertebrates living on dry land originally came from the sea, and are still continuing to adapt themselves to their present surroundings, where they can get but little salt." Von Bunge's theory was a great leap forward and had great effect as the sudden truth always does. Von Bunge (1902) said that he was advancing his theory for the first time.

There is a certain anomaly in the dating of von Bunge's publications which I have not resolved at this writing. I have not seen a fourth German edition of his *Lehrbuch*, etc. of which the 1894 edition is said to be the "Dritte Aufl." The situation is compounded by the listing of the American edition (P. Blakiston's Son and Company) of the English edition as the "Second English Edition." I know of no first English edition unless the London edition by Kegal Paul of the same date, a facsimile reproduction so far as I can see, is termed a first edition. This would be a bit odd and cavalier, but no more so than the English custom of ignoring hereditary titles such as the von of von Bunge, for everyone except the British. However, precise priority is not of deep importance and ideas may come from diverse workers at close periods or discoveries may come independently from various workers at closely related times.

A. B. Macallum at Johns Hopkins University was led to somewhat similar conclusions as those of von Bunge by a different approach. He first considered the salt ions in marine medusae (1903) and later considered the differences

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between animal and plant fluids as related to paleochemistry (1904) with a later treatment of vertebrates and invertebrates (1910). A summary of the whole question was reviewed by Macallum (1926). Macallum seems to have been more experimental than von Bunge, but his facts are no more trenchant or correct. Thus the whole situation seems to be an excellent example of how important new ideas spring at quite close times out of the *zeitgeist*.

Macallum seems to have been drawn to his conclusions by the similarity between the proportions of sodium, calcium, and potassium in blood and sea water. Lower concentrations in blood were explained by the great time elapsed since vertebrates left the sea. These reasons apparently satisfied Bayliss (1927) who quoted them on page 210. He added that sea water is a good physiological solution when diluted to the same osmotic pressure as the blood, although "the amount of magnesium is unnecessarily great." The same could be said of sulphate.

In the deep ocean where warm sea water has been found welling up from the magma in areas near the margins of the deep Earth plates a rich fauna has been found. Recent work has shown that little oxygen is available but there is an oxidation system depending on sulphate in the upwelling water.

The von Bunge-Macallum theory of the connection between sea water and vertebrate blood has been widely accepted and, therefore, not commented upon very much. Rogers (1927) presented the theory concerning marine origins in succinct terms:

> The first living organisms had the sea for their environment. Every cell doubtless came into contact with this fluid which was at the same time the source of its food and oxygen supply. As cells began to be associated in smaller or larger masses, channels were left between them through which the water of the sea might find passage. Animals a little further along the scale of development shut off their body cavities, vascular and otherwise, from direct communication with the sea, but did not succeed in freeing the cells from the necessity of getting their food and oxygen supplies from a solution. The fluid shut within the animal body furnished the immediate environment of the cells; it took the place of the sea in the environment of the organism. It has been seen that the fluid becomes more and more complex as one passes in review from lower to higher forms. And while the internal fluid sea, bathing the individual cells, has become more complex and able to play a greater variety of functions in the life of organisms, there are certain features in which it harks back to the primitive conditions which must have existed millions of years ago.

The only serious demurrer was advanced by Conway (1943, 1945) in two important papers showing the components of salt in the sea that have resulted from weathering and land drainage. He found poor correspondence between the components of land drainage and the salinity of the sea and that was accepted by some people as disproving the theory of blood connection with the sea. Actually there is no logical connection between the real origin of sea salt and the components of salt of mammalian blood. The important fact is correspondence or similarity which came about after the sea salt proportions were established.

In any case, it was shown later by Rubey (1951) that sea water comes chiefly from the magma and the deep earth and not from the atmospheric halogens. There has been no real dispute of Rubey's conclusions.

In 1957 Pearse and Gunter reviewed this question in a chapter on salinity and gave their adherence to the von Bunge-Macallum thesis. Since then nothing has transpired except that the theory of the freshwater origin of fishes has finally been laid to rest and rejected by a long series of papers which have disproved it on all points. All in all it is a side issue and will not be treated here. The chief modern protagonist of freshwater origin, A. S. Romer of Harvard, never gave up during his life, but to no avail so far as continuance of the theory was concerned. Today there are no adherents remaining, at least not any who wield the pen. And so the theory of marine origin of vertebrates and their blood now remains unquestioned.

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